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Steering of measurement processes with the aid of utility values

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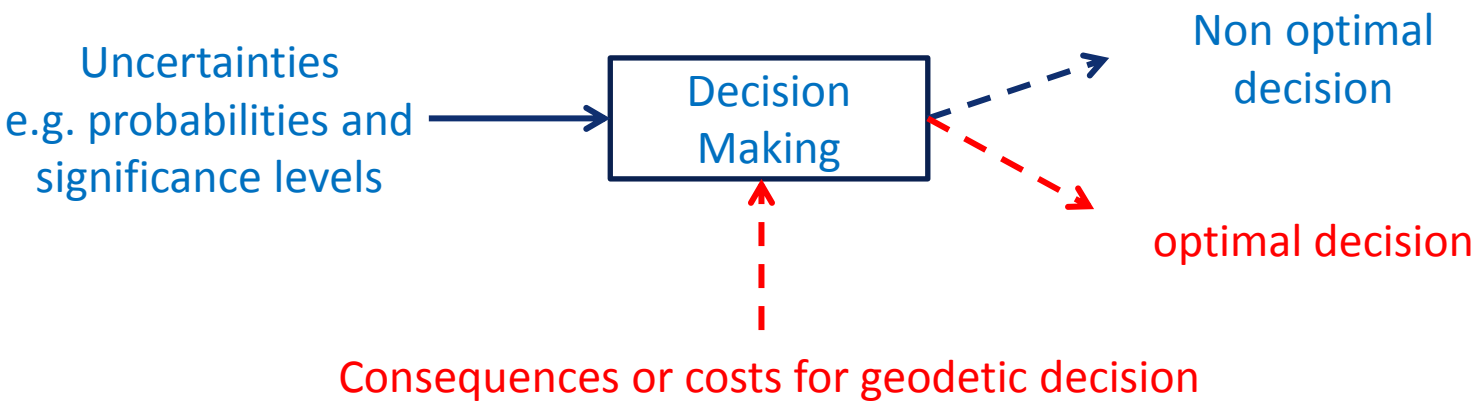
- **Main goal of geodetic deformation monitoring**

  - Minimising the risk of unexpected collapses of artificial objects and geologic hazards.

- **Current situation and problem**



Agenda

1. Motivation
2. Mathematical definition of the situations
3. General idea of the methodology
4. Examples
5. Conclusion and prospects

Mathematical definition of the situations

- **Three cases**

based on the information of the monitored object.

- **CASE I:** null hypothesis H_0 is known; alternative hypothesis H_1 is known. (example: a machine part)

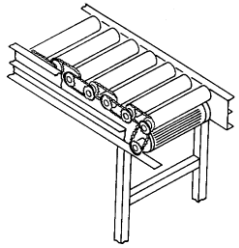
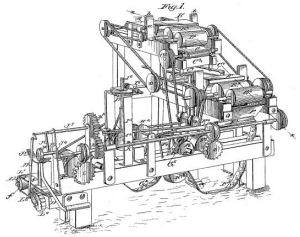
- **CASE II:** null hypothesis H_0 is known; alternative hypothesis H_1 is **not** known. (example: a machine part)

- **CASE III:** null hypothesis H_0 is **not** known; alternative hypothesis H_1 is **not** known. (example: a slide slope)

Y. Zhang and I. Neumann, "Risk assessment for slope monitoring", Journal of Applied Geodesy. Volume 7, Issue 3, Pages 159–171, 2013.

Mathematical definition of the situations

➢ Example with machines

Machine	Figure	Damage	Cost
Conveyor		A steel roller	€ 100
Expensive machine		Whole machine	€ 10,000

Q: How could it be considered?

⬇

Utility theory

➢ Utility theory

Main idea: to judge each possible decision with a utility value.

- Possible situations of classical hypothesis testing:

Situations	**Acceptance of H_0**	**Rejection of H_0**
H_0 is true	Correct choice of the null hypothesis U_{00}	Incorrect choice of the alternative hypothesis (**Type I error**) U_{01}
H_0 is false (H_1 is true)	Incorrect choice of the null hypothesis (**Type II error**) U_{10}	Correct choice of the alternative hypothesis U_{11}

➢ Decision making with cost functions

- The expected cost of null and alternative hypotheses:

$$K_0 = p_0(T)U_{00} + p_1(T)U_{10} = p_0(T)\left(U_{00} - U_{10}\right) + U_{10}$$

$$K_1 = p_0(T)U_{01} + p_1(T)U_{11} = p_0(T)\left(U_{01} - U_{11}\right) + U_{11}$$

Negative numbers

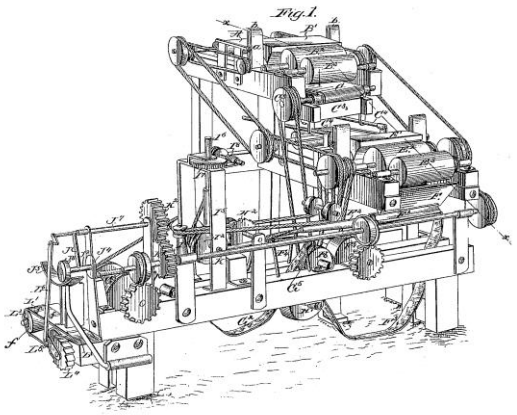
→ Make optimal decision with minimum costs or/and try to minimise the risk of an individual project.

$$p_0(T)U_{00} + p_1(T)U_{10} \geq p_0(T)U_{01} + p_1(T)U_{11}$$

$$p_0(T) \geq p_{0,\text{critical}} = \frac{U_{11} - U_{10}}{U_{00} - U_{10} - U_{01} + U_{11}}.$$

Decision: Accept H_0

Example: monitoring of a machine part



Requirement: standard length is 100 mm.

Question: Qualified to use?

Example: monitoring of a machine part

- **Determination of probabilities**

  - Based on Bayes' Theorem.

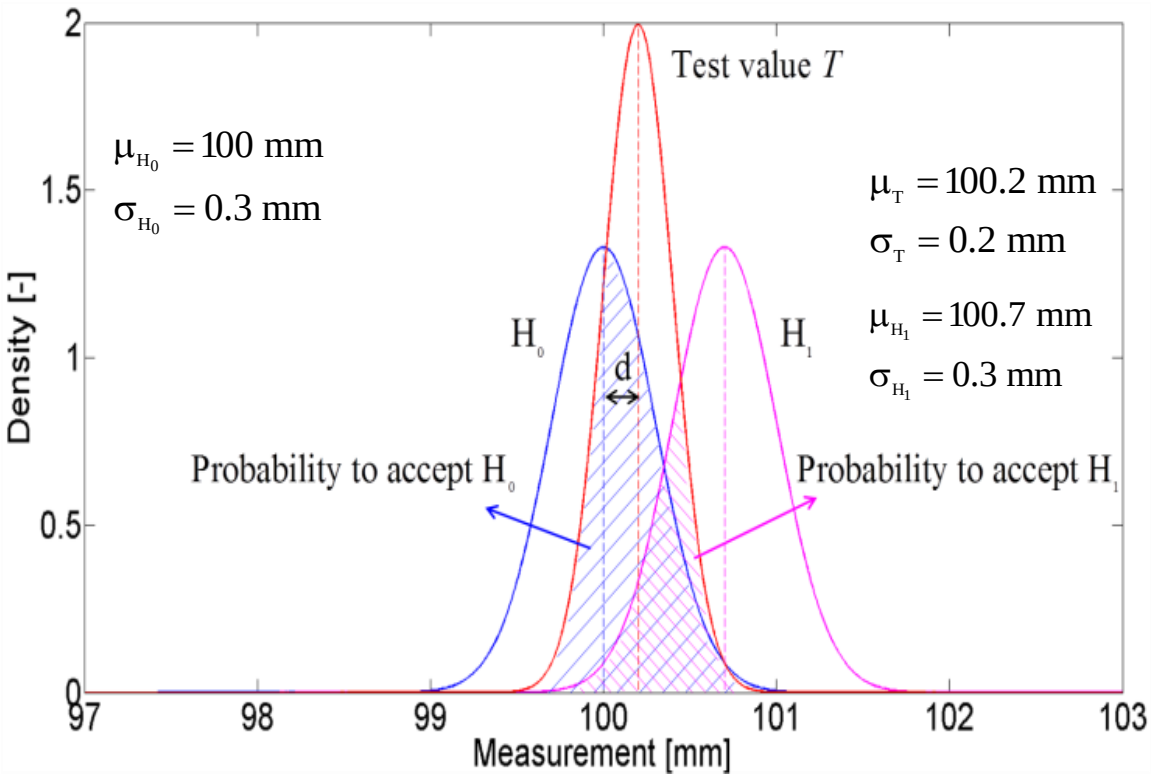
- **Utility values of the situations**

  - The minus sign stands for expense/costs.

Utility values	U_{00}	U_{01}	U_{11}	U_{10}
€	-2000	-3000	-3000	-10000

Example: monitoring of a machine part

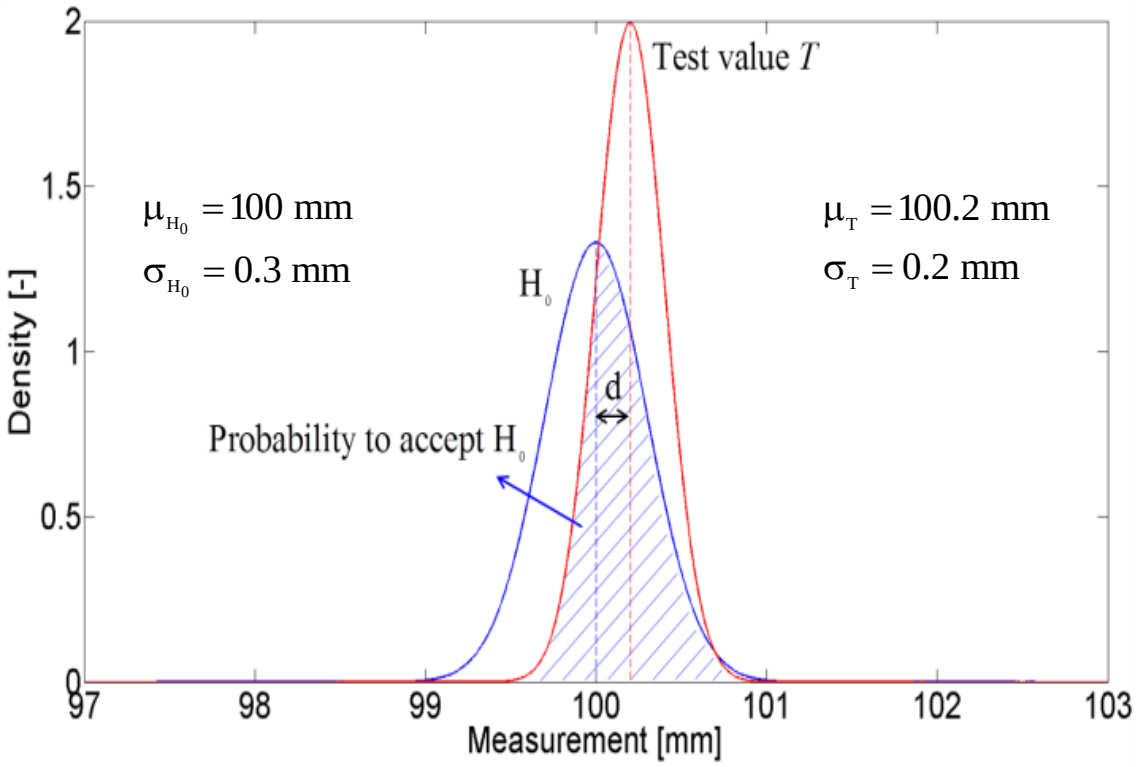
➢ **CASE I:** test value with random errors



Hypothesis	H_0	H_1
Probability	0.778	0.222
Expected Cost	3778.29	3000.00
Decision	Reject	Accept

Example: monitoring of a machine part

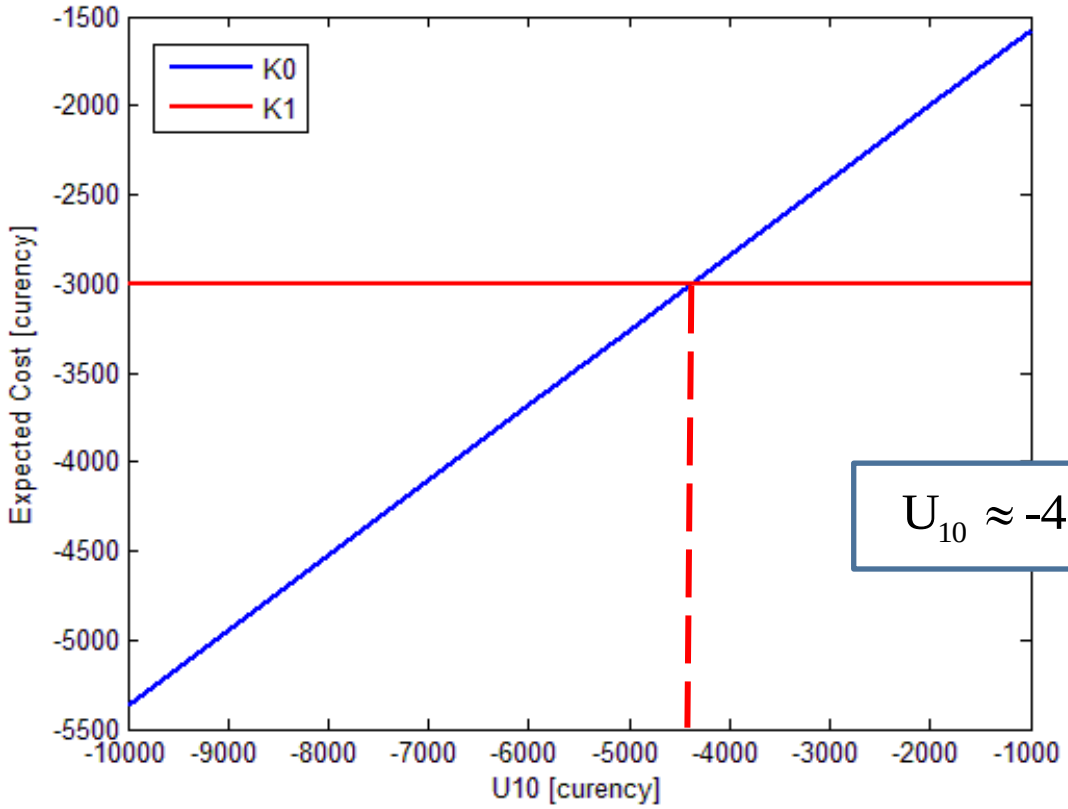
➢ **CASE II:** test value with random errors



Hypothesis	H_0	H_1
Probability	0.579	0.421
Expected Cost	5367.20	3000.00
Decision	Reject	Accept

- **Expected utilities with gradual changing U_{10}**

(e.g. CASE II: test value with random errors)

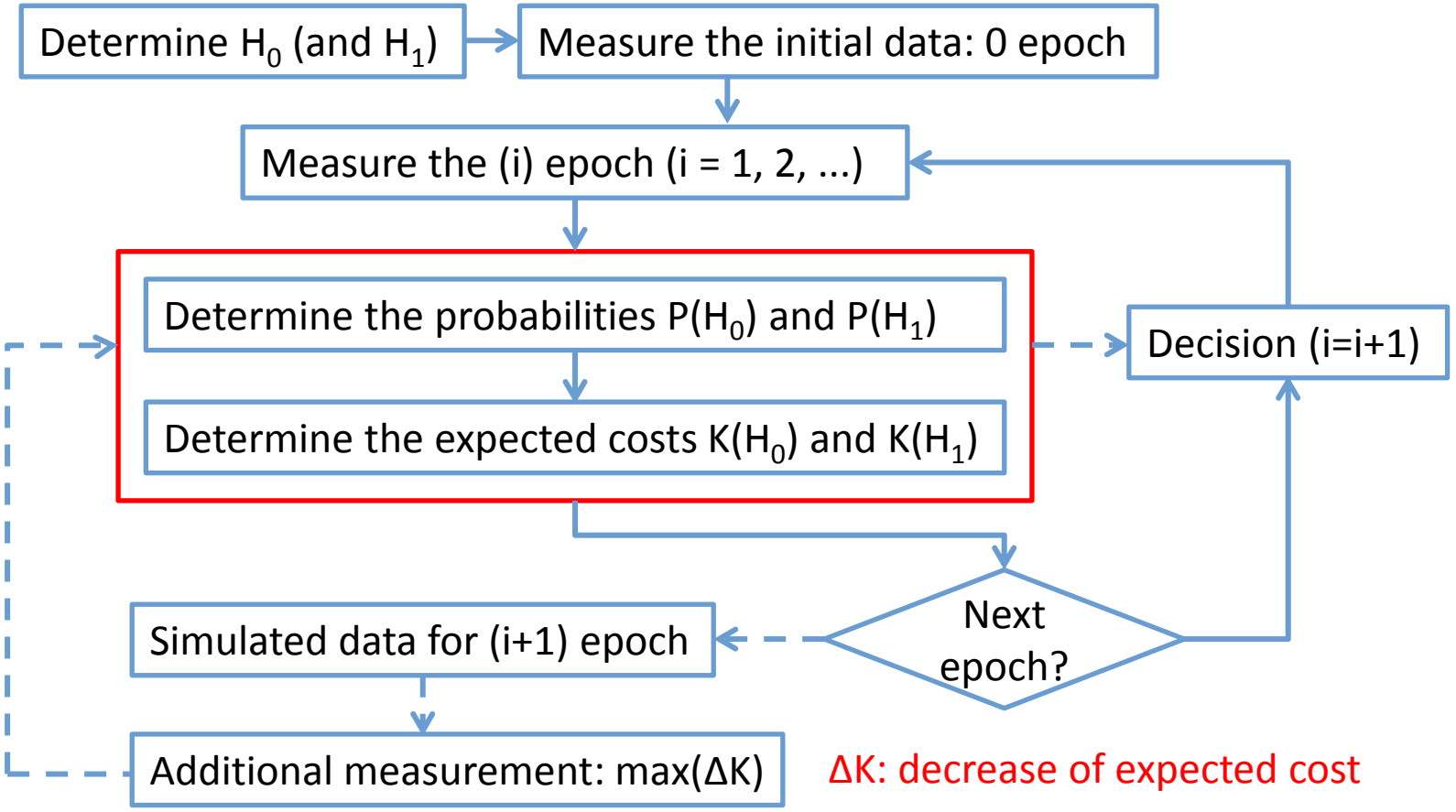


$$K_0 = p_0(T)\left(U_{00} - U_{10}\right) + U_{10}$$

$$K_1 = p_0(T)\left(U_{01} - U_{11}\right) + U_{11}$$

$U_{10} \approx -4375.86$

➢ Steering the process of bridge monitoring



➢ Conclusion for current results

- Consequences / costs can be considered in decision making.
- Find optimal decision to reduce risk of an individual project.
- Steering of measurements can be considered.

➢ Prospects

- More precise/reliable utility values are required.
- Extend the approach to multiple criteria decisions.
- Apply this strategy for steering a measurement project in reality.
- Evaluate the influence of the uncertainty of the utility values on the decisions.

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The presented paper shows results and new ideas developed during the research project NE 1453/3-1 "Steering and optimisation of measurement processes in consideration of cost functions", which is funded by the German Research Foundation (DFG). This is gratefully acknowledged by the authors.

Thank you for your attention.